Availability of sustainable biomass in Europe: framework conditions and projections from 2030- 2050

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Contents

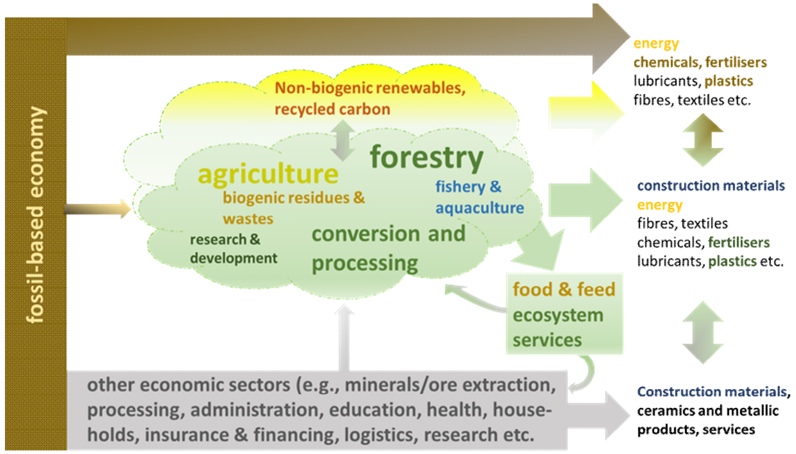
Context

Sustainable biomass supply

- highly debated, both at the scientific and at the political levels,
- … biomass value chains **can** deliver renewable raw materials, boost economic growth and rural development and increase farm income.
- …. concerns about the risks, that **unsustainable practices** for producing and using biomass can cause, to the already vulnerable planetary boundaries and finite natural resources such as land and water.
- This presentation discusses the **availability of sustainable, non-food, biomass in Europe** and presents recent projections for **2030 and 2050**.
- It also outlines conditions and assumptions under which the biomass potential can be sustainably optimised and contribute to human capital and welfare within safe planetary boundaries, without causing any other negative impacts (e.g., preserving high nature value areas, maintaining and improving soil carbon and biodiversity, et.).

Drivers for biomass

- Biomass for **construction materials, fibre, food and feed, furniture and textiles** will grow, especially innovative biomaterials such as bio-based chemicals, lubricants, and bio-based plastics which offer high value added per mass unit.
- Electrification is very important, but it is not the 'silver bullet for all'.
- Despite the impressive potential of wind and solar, biomass will provide **grid balancing services**, and help sectors difficult to be decarbonized through electricity, e.g. **aviation, heavy duty and maritime transport, and high-temperature industrial processes**. There is a complementary role of bioenergy and electricity until 2050.
- Biomass can deliver **social resilience**: locally produced biofuels and bioenergy can **support the local economy, create domestic jobs, enhance energy import independence, improve systemic resilience, and act against external fluctuations in energy prices and fuel supply.**



Biomass in sustainable futures

- Biomass (food, raw materials) is a natural resource within the provision of ecosystem services; it can grow and regenerate.
- Biomass availability is subject to safe operations within planetary boundaries & provision of social welfare.
- Sustainability criteria and indicators can deliver a commonly accepted operation framework for biomass provision.

Biomass (non- food) potential is diverse; efficient mobilisation is required

Mobilise residues (from agriculture and forestry operations) and the organic fraction of municipal wastes.

Increase yields with the use of varieties that are better adapted to local ecosystems, the introduction of crop rotations, the use of cover crops to prevent soil erosion in sensitive areas and at the same time increase crop production, etc.

Facilitate carbon farming practices (including conservation tillage, intercropping, cover cropping, rotational cropping that increases soil carbon and agroforestry which stores carbon in vegetation)

Enable crop cultivation in land that is abandoned and/ or remains underutilised or unused because it is marginal.

Assessing sustainable non-food biomass supply

Data sources & modelling (example)

BASELINE			'What if' assumptions	OUTPUTS
Supply & demand	GHG	Costs	Scenario runs	Projections/ validation
CAPRI: CAP & endogenous changes for oils, starch and sugar	Inventory of studies on iLUC; IFPRI-MIRAGE BioF	Market prices	Sustainability criteria & resource efficiency footprints	Understand & quantify impacts and mitigation options
Crop growth models for prediction of non food perennials	GEMIS database	Non food cost appraisal modelling	CAP, Farm2Fork, Biodiversity	Role of resource efficient value chains
Data from individual field trials across Europe to validate modelling results	Mittera Europe (with IPCC guidelines)	Data from individual field trials across Europe to validate modelling results	Yield, management practices for perennials & land typology	Policy interventions for supply
Data from energy & economic related databases	GLOBIOM, PRIMES, RESOLVE, GREEN-X, MAGNET, etc.	Sector demand	RED II; Green Deal, etc.	Policy interventions for shares of bioenergy/ biofuels

Framework conditions in biomass availability

Land availability (shifts from agriculture to forests, unused land, etc.)

Agronomic practices (carbon farming: rotations, agroforestry, etc.),

Species (annual/ perennial) and quality traits (high oil content, lignin, etc.)

Water management

GHG emissions

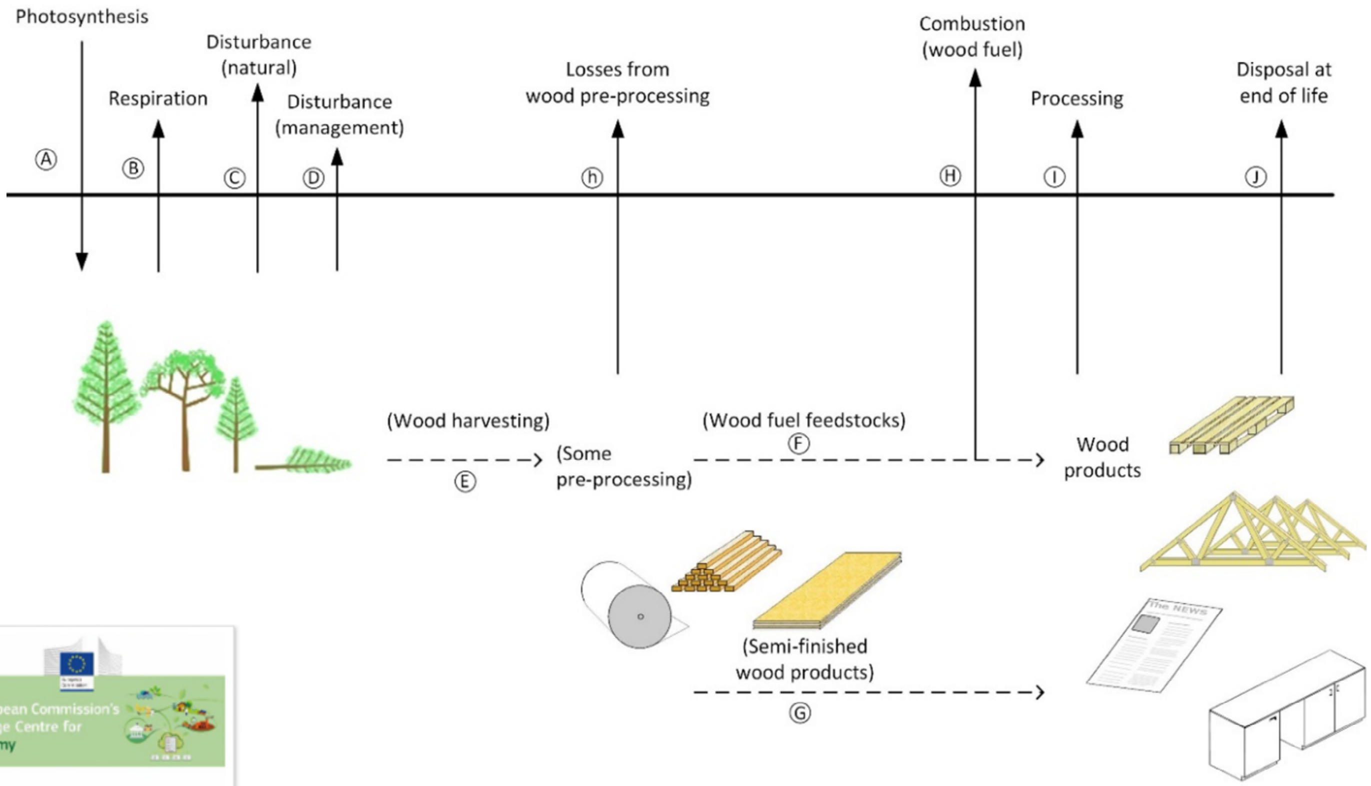
‘Carbon debt’ which refers to the time lag between CO_2 released from forest bioenergy when biomass is burned and the full re-absorption of this CO_2 through tree re-growth.

Biodiversity

Ecosystem services

Carbon (C)

- The C stocks in vegetation biomass, litter and soil represent a natural reservoir of C sequestered from the atmosphere.
- Biomass can be harvested and used for a range of products (e.g. energy, transport fuels, bioplastics, construction materials, paper etc.), some of which also represent a C reservoir and can be used to substitute for generally GHG-intensive non-biomass materials and energy sources. Although the lifetimes of products are temporary, some are long-lived, suggesting that the reservoir of carbon in products could also be “managed” to retain carbon stocks and as carbon sinks.
- Biomass be used to substitute for generally GHG-intensive non-biomass materials and energy sources. In situations where bioenergy derived from biomass can be regarded as having low GHG emissions, combination with CCS could contribute towards negative emissions



Matthews, Robert (2020) Synthesis report on Question 2: Bioeconomy development consistent with sustainable development and achieving net zero emissions. Final report prepared for EC DG RTD & JRC

Soil carbon in agriculture with carbon farming

Carbon farming refers to ecological farming practices that can sequester carbon and/ or reduce GHG emissions.

Agricultural activities for carbon sequestration include conservation tillage, cover cropping and rotational cropping.

Carbon sequestration in agricultural soils can help to improve soil structure and nutrient storing capacity, reduce erosion, increase soil moisture retention and plant available water.

Co-benefits for farmers: improving soil quality, reducing soil erosion, enhancing biodiversity, selling carbon credits, improving landscape appearance and GHG mitigation/carbon storage.

EUROPEAN COMMISSION

Brussels, 15.12.2021
COM(2021) 800 final

COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT AND THE COUNCIL

Sustainable Carbon Cycles

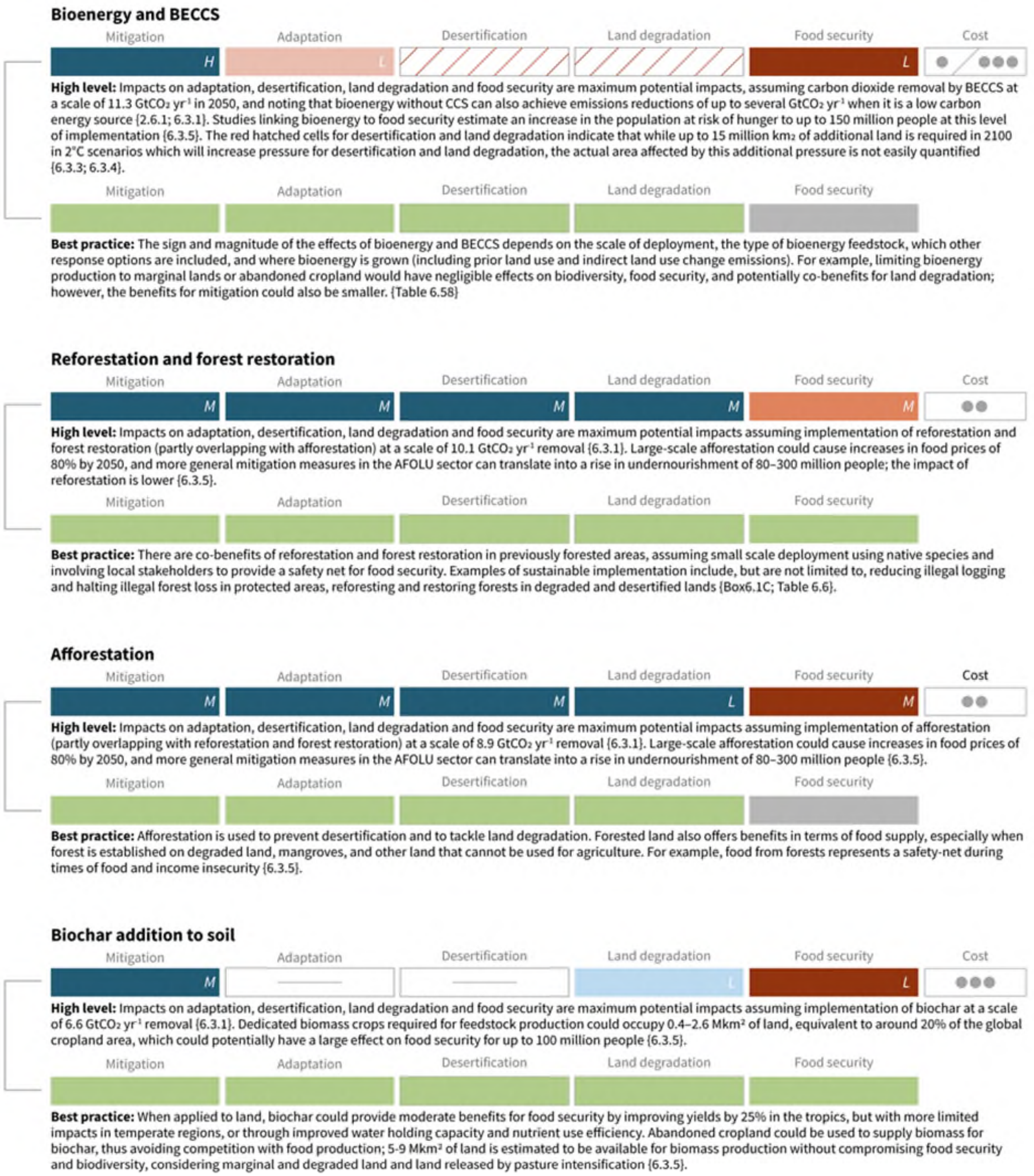
{SWD(2021) 450 final} - {SWD(2021) 451 final}

https://ec.europa.eu/clima/system/files/2021-12/com_2021_800_en_0.pdf

Biodiversity

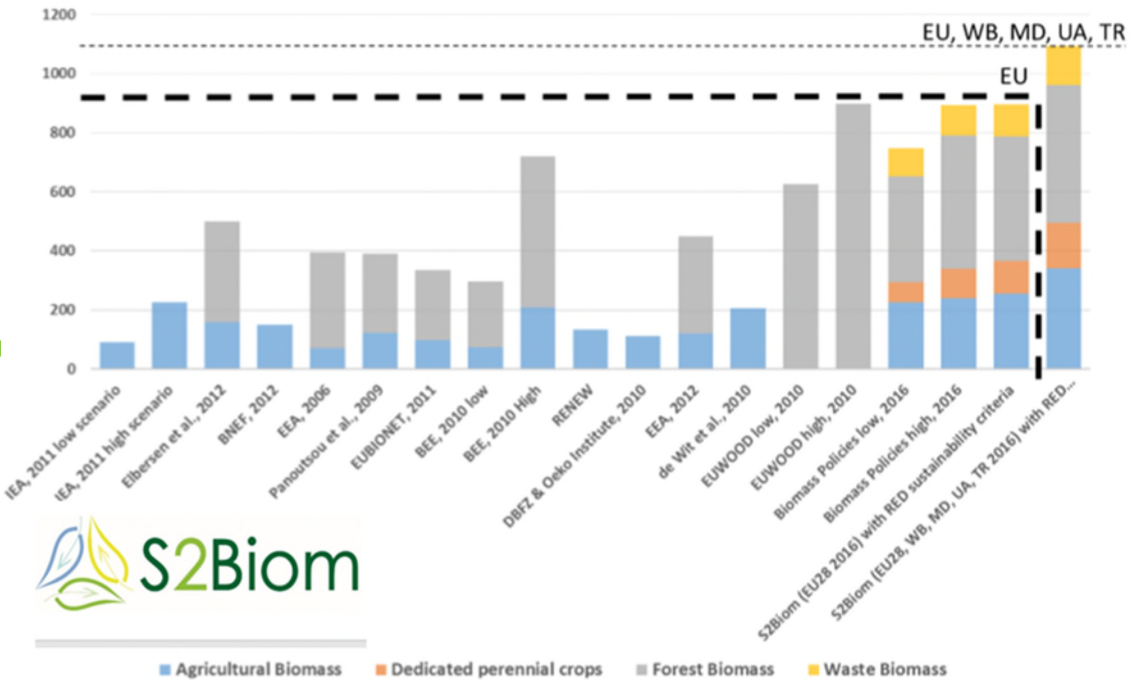
- Conservation of land with significant biodiversity values (such as areas of High Nature Value, NATURA, etc.) which usually covers protected sites. The category assesses the risk of disturbing conservation land, including NATURA2000 and High Nature Value (HNV) farmland. No such land can be considered as available for biomass feedstocks.
- Land management without negative effects on biodiversity: accounting for cultivation practices which are based on the following principles:
  - use of domestic species and local varieties,
  - avoiding monocultures and invasive species,
  - preferring perennial crops and intercropping,
  - use of methods causing low erosion and machinery use, low fertilizer and pesticide use and avoiding active irrigation.

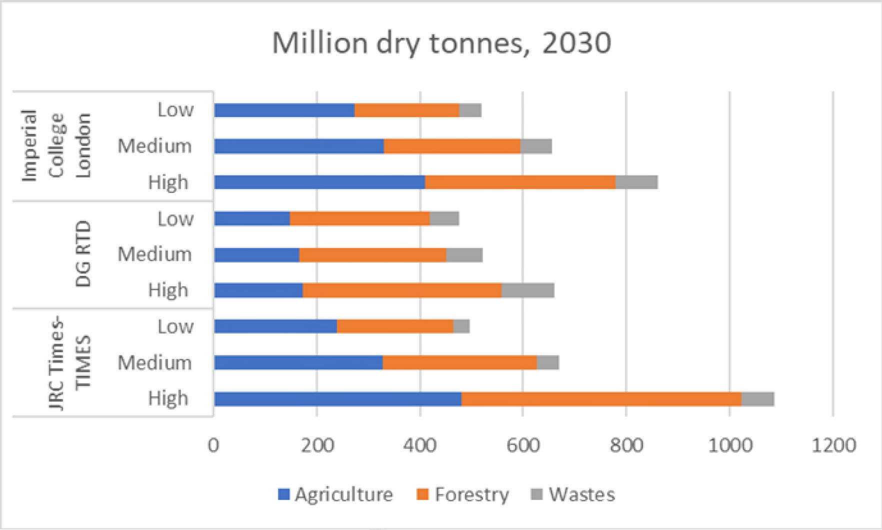
IPCC comparison of biomass-based climate change mitigation options

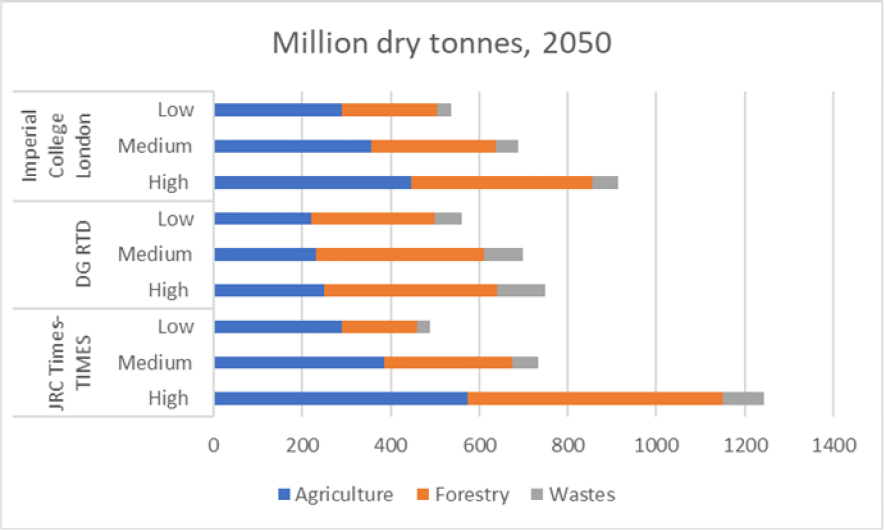


What influences ranges?

- Yields
- Improved practices & equipment
- Improved local knowledge
- Increased innovation that drives improved Technological Readiness Level





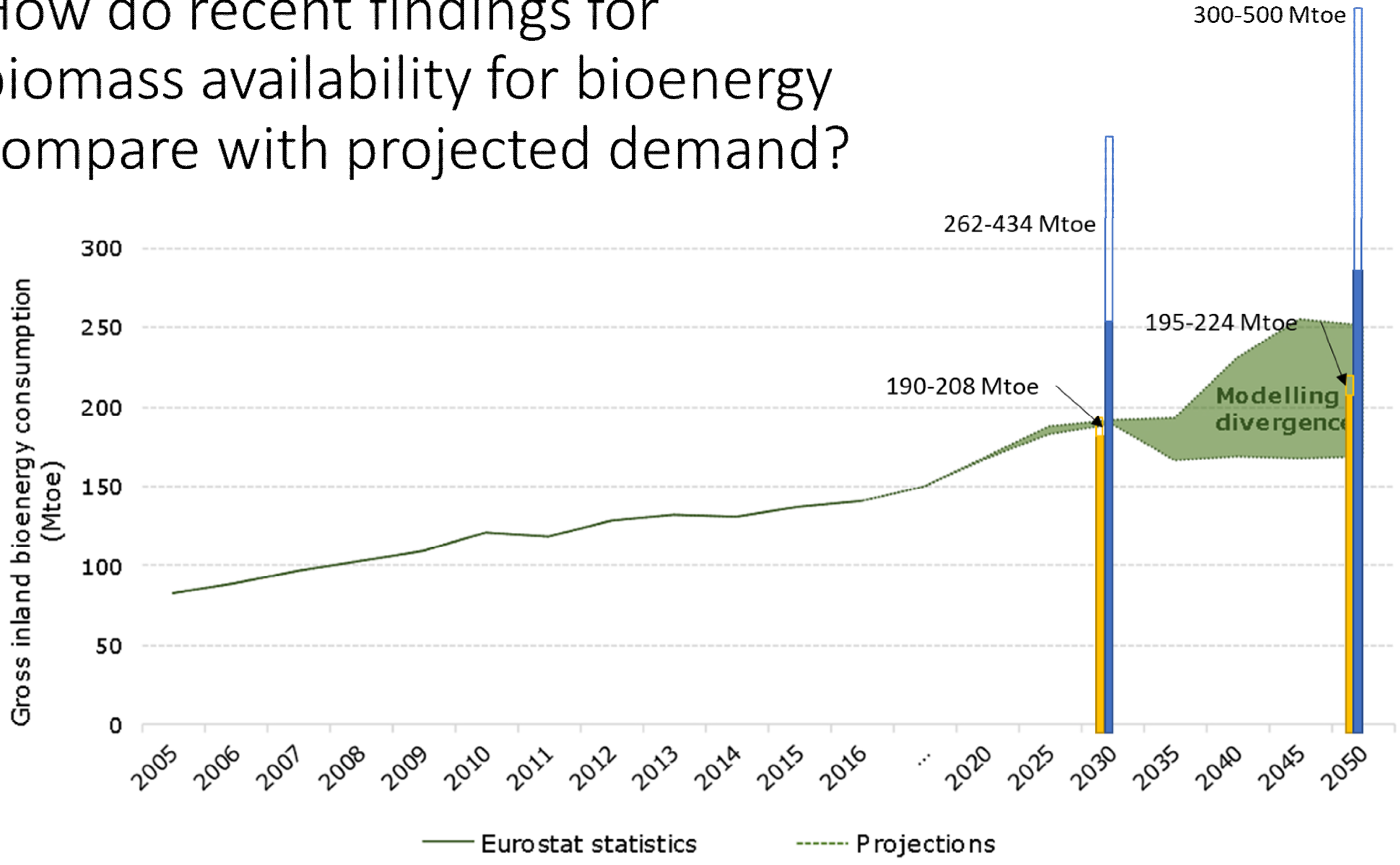


Prioritisation based on technological maturity & markets- the case for advanced biofuels

Panoutsou C., Germer S, Karka P., Papadokostantakis S., Kroyan Y., Wojcieszyk M., Maniatis K., Marchand P. 2021. Advanced biofuels to decarbonise transport by 2030: Markets, challenges, and policies that impact their successful market uptake. Energy Strategy Rev. Volume 34, March 2021, 100633. https://doi.org/10.1016/j.esr.2021.100633

Raw material	Conversion pathway	Biofuel type	Status TRL	Fuel	Market
Waste oils and fats, Used Cooking Oil (UCO), non-iLUC Veg oils, liquid waste streams and effluents	Esterification or transesterification	Traditional biodiesel (FAME)	Commercial	Blends with fossil diesel, B7 (drop-in), B10, B30 or neat FAME	
	Hydrotreatment	Hydrotreated Vegetable Oil (HVO) / renewable diesel		Drop-in blends with road diesel (i.e. H30) or neat HVO, Sustainable Aviation Fuels	
MSW, sewage sludge, animal manures, agricultural residues, energy crops	Biogas or landfill production & removal of CO2	Biomethane		bioCNG; bio-LNG in heavy-duty road, LBG in marine and CBG in light-duty road transport, captive fleets or injected in the gas grid	
Lignocellulosic, MSW, *solid* industrial waste streams/residues	Enzymatic hydrolysis & fermentation	Ethanol	TRL 8-9	Gasoline blends such as E5, E10 (drop-in), E20 (minor engine modifications), E85 flexi-fuel engines), ethanol with ignition improvers for diesel engines (ED95), or ethanol/butanol upgraded to biokerosene (ATJ)	
		Other alcohols (methanol, butanol)	TRL 6-7		
	Gasification + fermentation	Ethanol	TRL 6-7		
Lignocellulosic, MSW, *liquid* industrial waste streams & effluents or intermediate energy carriers	Gasification + catalytic synthesis	Synthetic fuel	TRL 6-7	Drop-in blends with diesel, gasoline, Sustainable Aviation Fuels, bunker fuel or as pure biofuel e.g. bio-SNG, DME, methanol,	
Pyrolysis oils or biocrudes from lignocellulosic, MSW, waste streams	Pyrolysis or liquefaction (i.e. HTL) + Hydrotreatment	Hydrotreated bio-oil/biocrude	TRL 4-5	Neat or drop-in diesel, bunker fuel, gasoline, Sustainable Aviation Fuels	
	Co-processing in existing petroleum refineries	Co-processed bio-oil/biocrude	TRL 7-8	Neat or drop-in diesel, bunker fuel, gasoline, Sustainable Aviation Fuels	
CO_2 from RES systems	Reaction with RES H_2	Synthetic	TRL 6-7	Depends on fuel type, i.e. bio-SNG, methanol or DME, ATJ	

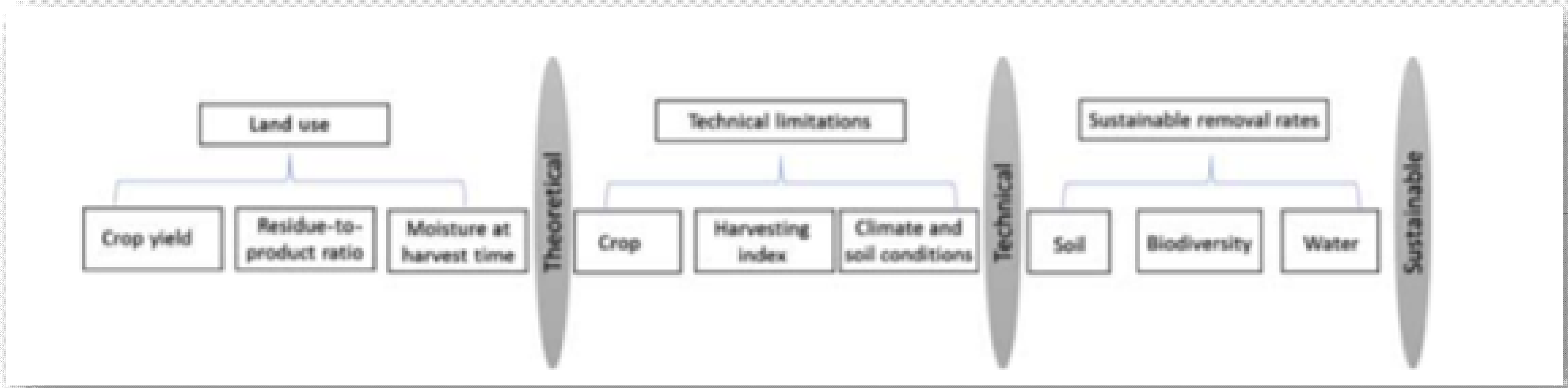
How do recent findings for biomass availability for bioenergy compare with projected demand?

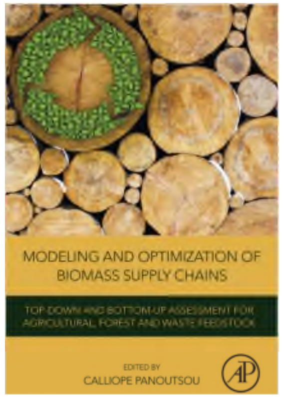


JRC (2019c) Brief on biomass for energy in the European Union. Scarlat, Nicolae et al. European Commission's Knowledge Centre for Bioeconomy. Joint Research Centre JRC109354. Ispra https://doi.org/10.2760/546943

Biomass from agriculture

Type of biomass		Definition	Sustainability issues
Straw/ stubbles	Cereals	Dried stalks of cereals (including rice), rape and sunflower which are seperated from the grains during the harvest. Often these are (partly) left in the field.	Loss of SOC and nutrients at too high straw removal rates.
	Rape-sunflower		
	Rice		
	Grain maize (stover)	Corn stover consists of the leaves, stalks and empty cobs of grain maize plants left in a field after harvest	
	Sugarbeet leaves & tops	The sugareet leaves and tops are the harvest residues seperated from the main product, the sugar beet, during the harvest and (often) left in the field.	
Pruning/ cutting	Apple, pear & apricot pruning	The prunnings and cuttings of fruit trees, vineyards, olives and nut trees are woody residues often left in the field (after cutting, mulching and chipping). They are the result of normal prunning management needed to maintain the orchards and enhance high production levels.	Loss of SOC and nutrients at too high residue removal rates
	Cherries and other soft fruits		
	Vineyards		
Other agro-industrial residues	Other organic industrial residues	Agro-industries process primary agricultural products into final products through pealing, crushing, drying, etc. and in this results in many vegetal residues (e.g. soya and rape cake, seed husks, etc.). The processing of animal products in slaughterhouses goes together with large amounts of organic residues such as bones and fats which are not always suitable for human or animal consumption and can be treated as residues for other nonfood/feed purposes.	Competition with animal feed





Panoutsou C, Perakis C, Elbersen B, Zheliezna T, Staritsky I (2017) Chapter 7—assessing potentials for agricultural residues. In: Panoutsou C (ed) Modeling and optimization of biomass supply chains. Academic Press, pp 169–197. doi:https://doi.org/10.1016/B978-0-12-812303-4.00007-0

Calculating primary agricultural residues & straw

Critical factor: Soil carbon

The calculation of the residue-to-yield factor is applied to the main product yield (grains) to estimate the above ground biomass production per crop in the following formula:

RESIDUE_YIELDi = AREAi * YIELDi * RESIDUE_2_YIELDi * DM_CONTENTi.

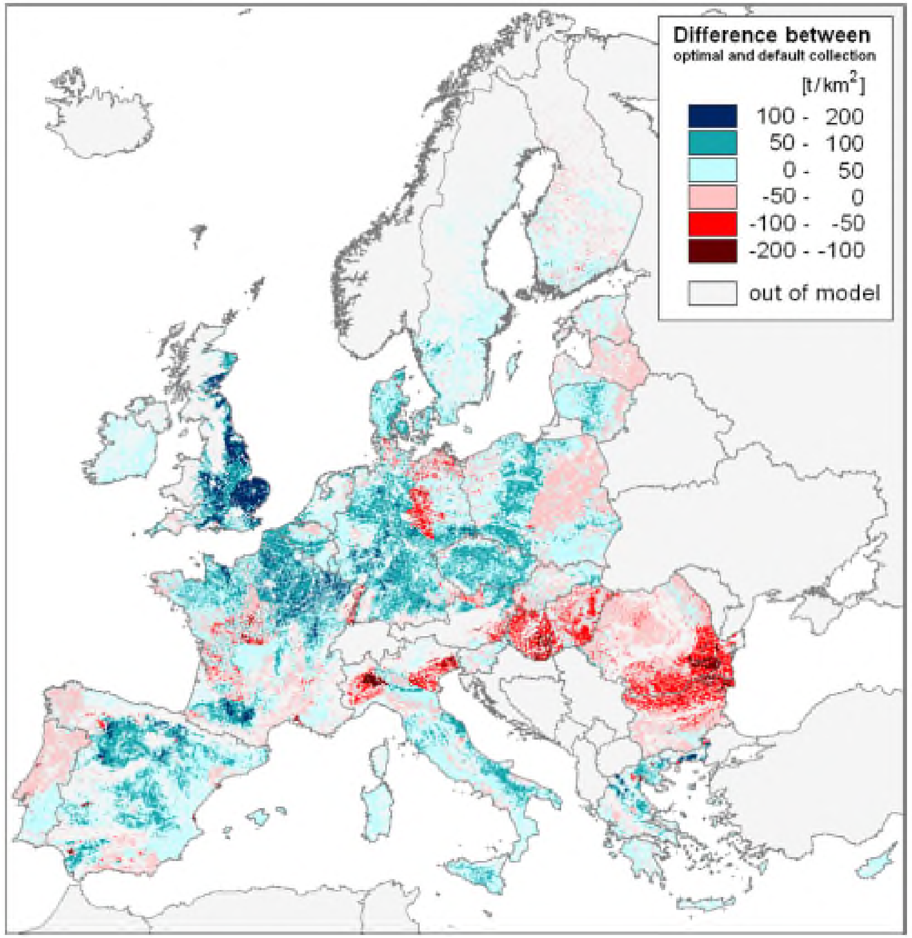
Where:

- RESIDUE_YIELDi = above ground biomass of crop i
- AREAi = Crop area of crop i
- YIELDi = Yield level of the main product (grains/seeds) of crop i
- RESIDUE_2_YIELDi =Residue-to- yield factors for crop i .

  See Table 3.6 for residue-to-yield factors identified in different studies:
- DM_CONTENTi= Dry matter content of crop i

DM content reported by Scarlat et al. (2010) are as follows:

- All cereals: 85%
- Grain maize: 70%
- Rice: 75%
- Sunflower: 60%
- Oil seed Rape: 60%



Map from the Montforti et al. (2015) study showing in red the places where 50% and higher straw removal rates lead to a decline in SOC and the blue areas allow for a 50% higher straw removal rate without decline the SOC.

Prunnings, cuttings

$$RESIDUE\_YIELD_i = AREA_i * RES\_YIELD_i * DM\_CONTENT_i.$$

Where:

- RESIDUE_YIELDi = total pruning yield of crop i in Ton/Year in dry mass
- AREAi = Crop area of crop i
- RES_YIELDi = Pruning yield Ton/Ha/Year in fresh mass of crop i
- DM_CONTENTi= Dry matter content of prunings of crop i

All residue yields from all crops can then be added up to come to a total pruning yield per country.

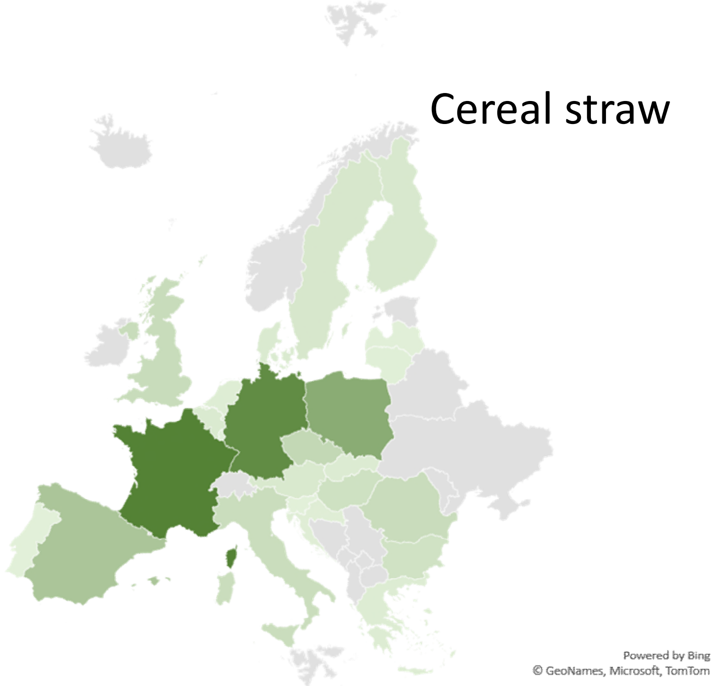
	Greece: M. Mardikis, et al. (2004)	Del Blasi et al. (1996)	Portugal: Diaz and Azevedo (2004).	S (2
Apples & pears	1.20-2.51	0.1-0.2	0.26-0.28	
Cherries and other soft fruit	1.2		0.47	
Nuts and other plantations	0.28	1.9	2.51	
Citrus plantations	1.55-2.90	0.1	0.15-0.17	
Olives	0.98	0.5-2.6	0.47	
Vineyards	1.2	0.2-0.8	0.39	

Crops	Country	Growing system (descriptive)	Pruning Type	Pruning Freq.	Row width (m)	Pruning period (J F M A M J J A S O N D)	Pruning production $(t/ha/y)_{fm}$
Olive	Spain	Typical traditional (↓)	Manual	1 or 2	7-12		1-4
		Intensive (↑)	Combined	1	4		n.d.
	Italy	Typical traditional (↓)	Manual	1	7		1.6 – 2.1
Citrus	Spain	Old pattern (↓↓)	Manual	1			n.d.
	Spain	Intensive, bush	Combined	1	2-3		3.7-9.3
	Italy	Intensive, bush	Combined	1	5		0.7 – 1.9
Almond	Spain	Intensive	Combined	1	4		≈1
		Rainfed	Manual	1 or 2	7		0.4-1
		Irrigated (high vigour) (↓)	Manual	1 or 2	6-7		≈1
		Irrigated (low vigour) (↑)	Combined	1	5-6		n.d.
Hazelnut	Italy	Rainfed	Manual	1	5		1.5-3
	France	Traditional	Manual	1	8		2.3
Chestnut	France	Traditional	Manual	1	8		1.2
Walnut	France	Traditional	Manual	1	10		1.9-3.2
	France	Intensive (↑)	Combined	1	8		---
	Ukraine	Traditional	Manual	1 or 2	10		n.d.
	Ukraine	Intensified	Manual	1 or 2	5		3
	Slovakia	Traditional	Manual	1	10		n.d.
Stone fruits (peach, apricot, nectarine and plum)	Spain	Semi intensive	Manual or combined	1	5-6		2-3
		Semi extensive	Manual	1	6-7		2-3
	Italy	Non intensive	Manual / Combined	1	4-6		2.6-3
		Intensive (↑)	Combined	1	4		2.6-3
	France	Non intensive	manual	1	4-5		2-3
		Intensive	Combined	1	3		n.d.
	Slovakia	Non intensive (vase)	Manual	1	5-6		n.d.
		Intensive	Manual	1	3		n.d.
	Ukraine	Traditional plum	Manual	1	5-6		nd
		Intensive plum	Manual	1	4-5		4.4
Cherries	Spain	Non-intensive	Manual or combined	1	5-6		2-3
		Intensive	Manual	1	4-5		2-3
	Italy	Non-intensive	Manual / Combined	1	6		2.6-3
		Intensive (↑)	Combined	1	5		2.6-3
	Poland	Traditional	Manual	1	5-6		3-6
		Intensified	Manual	1	4-5		2-5
	Ukraine	Traditional	Manual	1	5-6		< 10
		Intensified	Manual	1	4-5		< 10
Sour cherries	Poland	Traditional (↓)	Manual	1	5		3.6
		Intensified (↑)	Manual	1	4		3-5
		Superintensive	Combined	1	4		n.d.
	Ukraine	Traditional	Manual	1	5-6		n.d
		Intensified	Manual	1	4-5		4.4
Vineyard	Italy	Vase	Manual	1	4		1.8-2.9
		Espalier	Combined	1	2-6		1.8-2.9
	Spain	Vase (rainfed)	manual	1	3-4		1-2

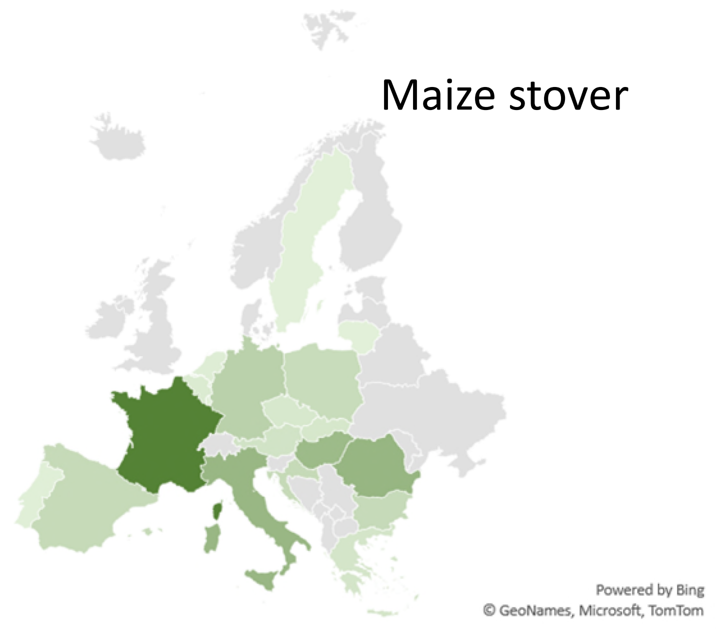
Source: CIRCE (2015). D3.1 Mapping and analysis of the pruning biomass potential in Europe. EuroPruning project

Agricultural feedstocks

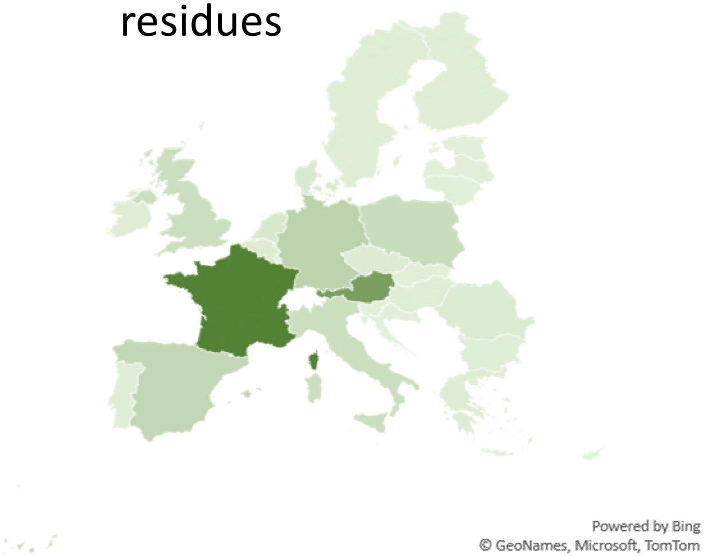
Cereal straw



Maize stover

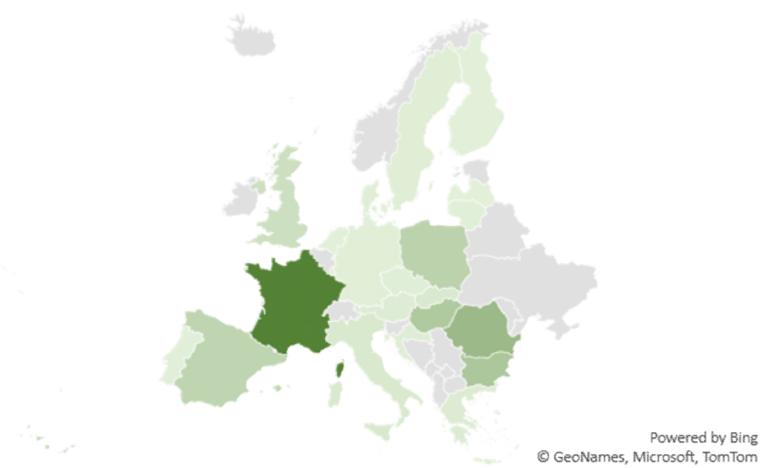


Agro-industrial residues



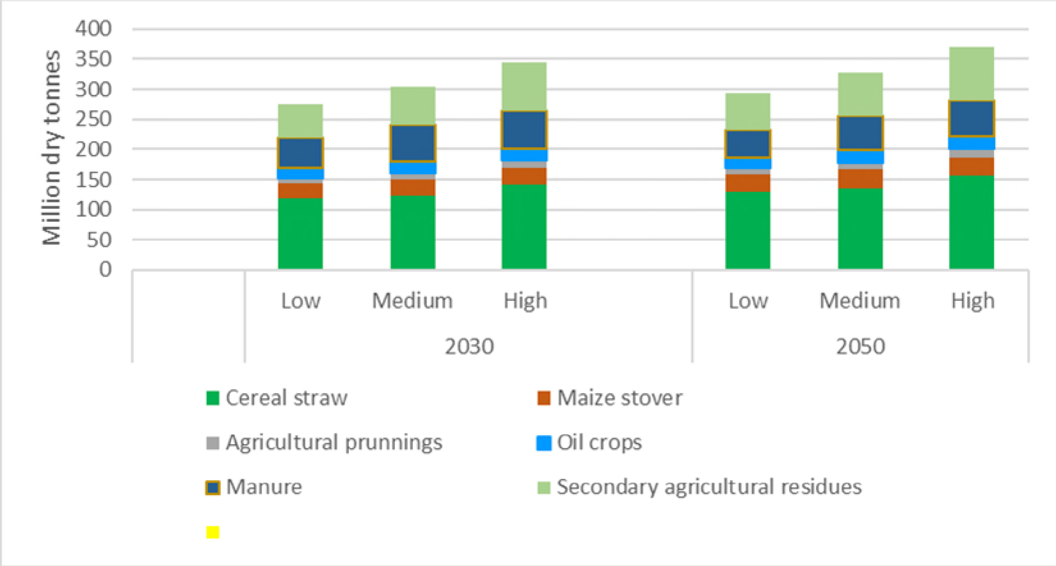
Agricultural prunnings

Oil crop residues



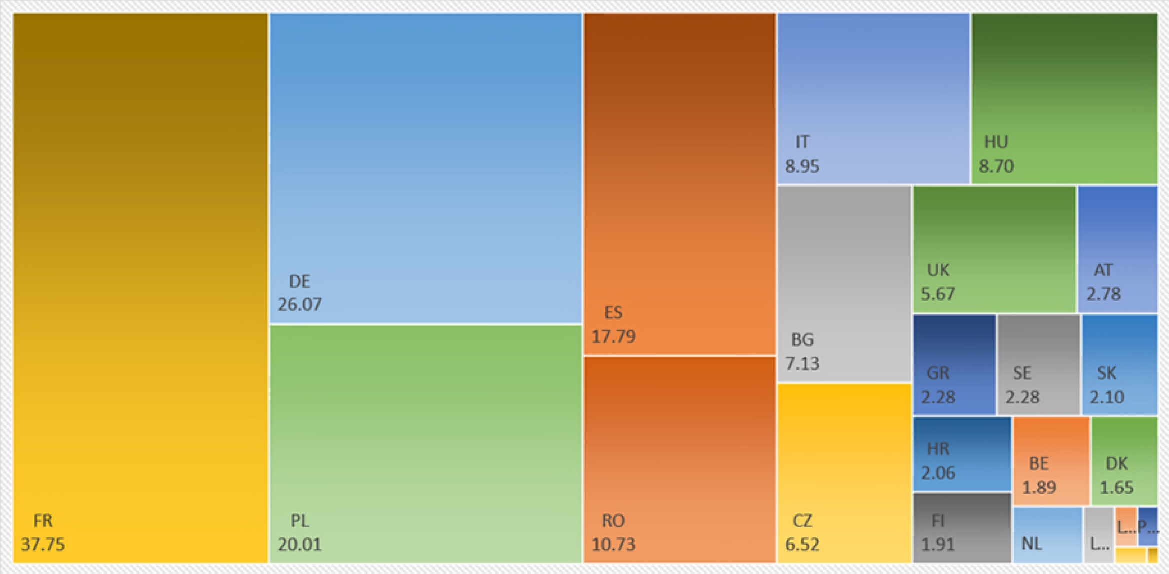
Estimated biomass potential from agriculture for all markets

Estimated biomass potential from agriculture



275 -370 million dry tonnes

Regional distribution



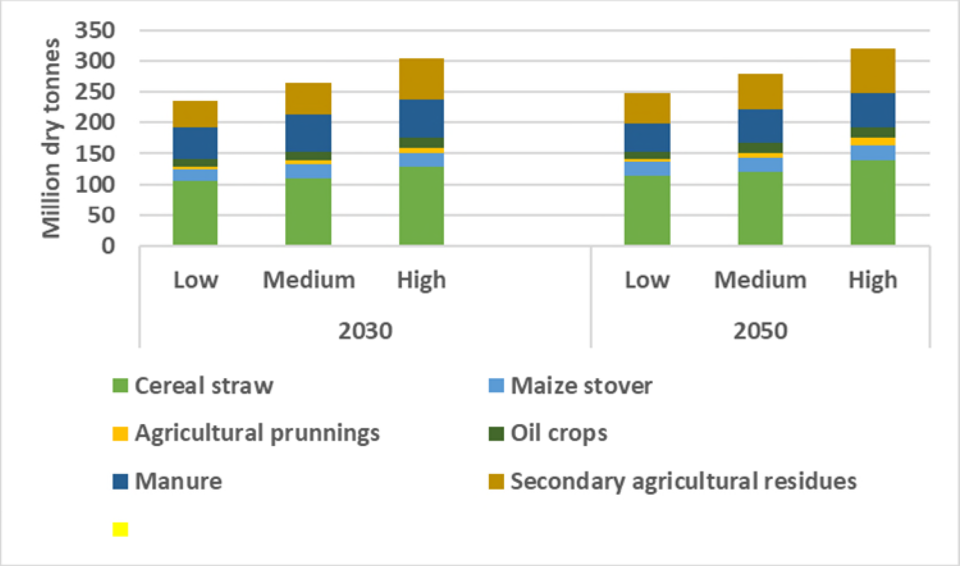
Note: Regional distribution for Scenario 1 (million dry tons).
Similar for Scenario 2 and 3

Key assumptions

	Scenario 1 (Low)	Scenario 2 (Medium)	Scenario 3 (High)
Agriculture			
Removal rate of field residues	40%	45%	50%
Use of prunings	5%	20%	50%
Moderate yield increases in perennial lignocellulosic crops in unused, degraded and abandoned land	1%	1%	2%
Share of unused, degraded and abandoned land for dedicated crops, excluding biodiversity rich land and land with high carbon stocks (Current share of unused, degraded and abandoned land for dedicated crops: No official statistics- only experiments and demonstration scale)	25%	50%	75%

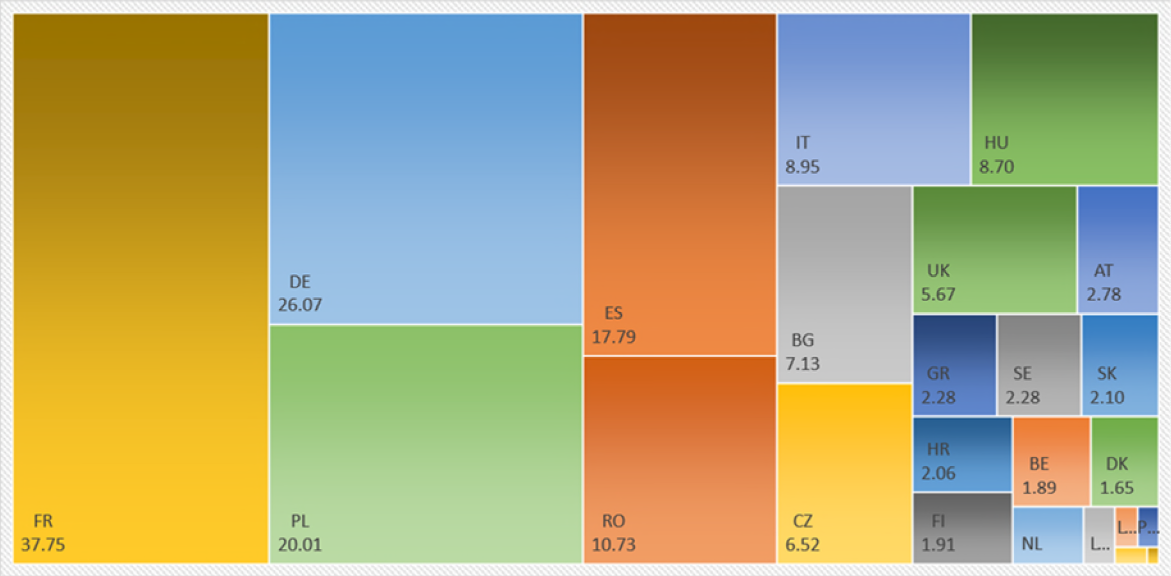
Estimated biomass potential from agriculture for bioenergy

Estimated biomass potential from agriculture



236 -320 million dry tonnes

Regional distribution



Note: Regional distribution for Scenario 1 (million dry tons).
Similar for Scenario 2 and 3

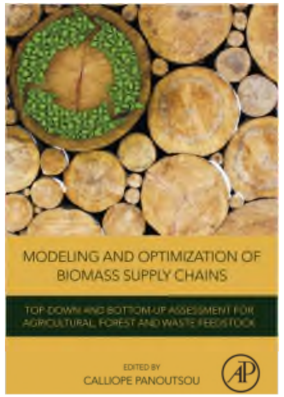
Ligno-cellulosic crops

Type of biomass		Definition	Sustainability issues
Ligno cellulosic crops	Miscanthus	Ligno-cellulosic perennial crops grown on existing agricultural lands, but also suitable to be grown on lower quality lands that can be defined as 'marginal' and abandoned lands. These perennials are produced plantations have a lifetime of 15 to 20 years and the biomass harvest takes place at a yearly basis starting from the 2nd year onwards. The yield consists of the whole plant which grows back every year when cut off just above the ground.	Risk for loss of semi-natural farmland habitats, direct land use and landscape structural changes which can have negative but also positive impacts for biodiversity
	Switchgrass		
	Reed Canary Grass		
	Poplar	Woody crops grown on existing agricultural lands, but also suitable to be grown on lower quality lands that can be defined as 'marginal' and abandoned lands. These crops are perennials grow in a short rotation coppice system which implies that their plantations have a lifetime of around 20 years and the biomass harvest takes place every 3 years useually from the 3rd year onwards. The yield consists of the whole plant which grows back every 3 years until harvested again.	
	Willow		

Crop	Photosynthetic Pathway	Drought Tolerance	Water Requirement (mm)	Growing Tmax (°C)	Growing Tmin (°C)	GDD[a] (°C)	Kc[b]	WP[c] (g/L)	HI[d] (%)
Miscanthus	C4	High	>500	40	10	1700–2000	0.47–1.4	1.9–4.7	0.7
Switchgrass	C4	High	450–750	35	10	2060–2540	0.5–1.3	2.6–3.9	0.6
Giant reed	C3	High	380–650	35	5	1843–3000	0.5–1.7	2–6	0.7
RCG	C3	Medium	400–900	30	7	1800	1.24–1.46	1.5	0.6
Ca[illegible]oon	C3	High	300–400	35	5	2425	0.5–1.0	3.13	0.6
Will[illegible]	C3	Low	>620	30	0	2200	0.49–2.7	2.9–6.3	0.65
Pop[illegible]	C3	Medium	>600	30	0	2200	0.42–2.5	3.35–5.26	0.6
[illegible]calyptus	C3	Medium	>500	35	5	2400	0.50–1.8	1.64–4	0.65

[a]GDD, growing degree days is the sum of daily temperatures from the start to end of the season to predict plant development rates.
[b]Kc, crop coefficient refers to a ratio between crop evapotranspiration and reference evapotranspiration.
[c]WP, water productivity refers to crop production in relation to total water consumed.
[d]HI, harvest index refers the ratio of yield to biomass. Some crops encounter more losses at harvest than others.
Source: Alexopoulou et al. 2010; Bassam, 2010; EEA, 2007; Zegada-Lizarazu et al. 2010; Lewandowski et al. 2003; Kretschmer et al. 2012; Fernandez et al. 2006.

Ramirez-Almeyda, J.; Elbersen, B.; Monti, A.; Staritsky, I.; **Panoutsou, C.**; Alexopoulou, E.; Schrijver, R.; Elbersen, W. Chapter 9 — Assessing the Potentials for Nonfood Crops. In *Modeling and Optimization of Biomass Supply Chains*; Elsevier: Amsterdam, The Netherlands, 2017; pp. 219–251. https://doi.org/10.1016/B978-0-12-812303-4.00009-4



Land abandonment & marginalisation

Agricultural land which will become available as crop productivity increases; high yields for all crop types

Mitigation target for bioenergy (fuels, heat and electricity) of 60% as compared to fossil alternatives, without including compensation of iLUC-related emissions.

Fischer et. al, 2010/ EEA, 2006

High restrictions for sustainability; average yields for all crop types

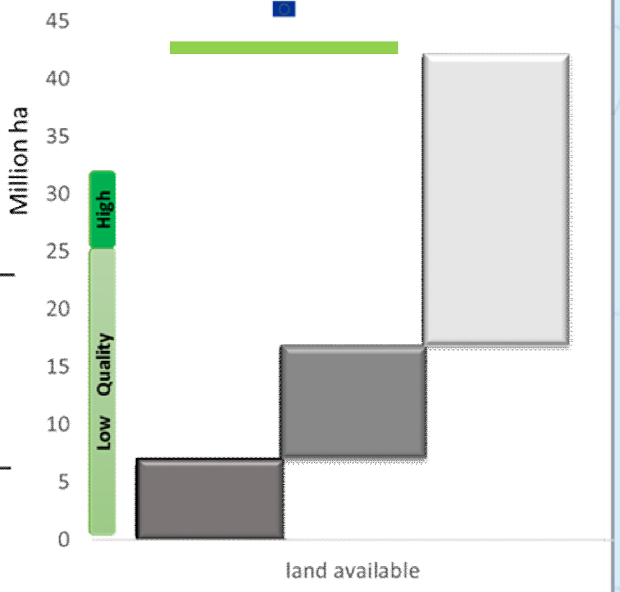
Mitigation target for bioenergy (fuels, heat and electricity) of 70% as compared to fossil alternatives, including compensation of ILUC-related emissions.

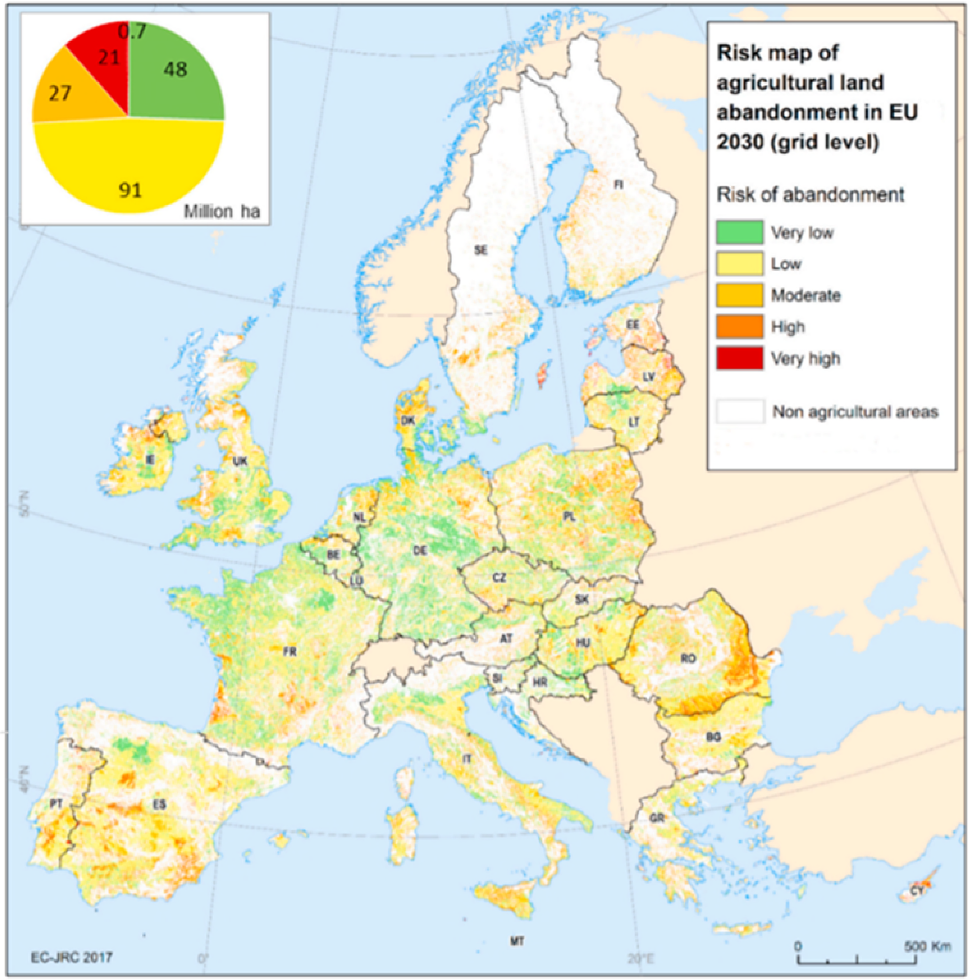
No use of biomass cropped on biodiverse land, land with high carbon stock and fallow land.

Biomass Futures, 2012/ EEA, 2013

Low quality and marginal types of land; low yields for all crop types

European Commission Impact Assessment for the Biobased Industries Joint Undertaking, 2014

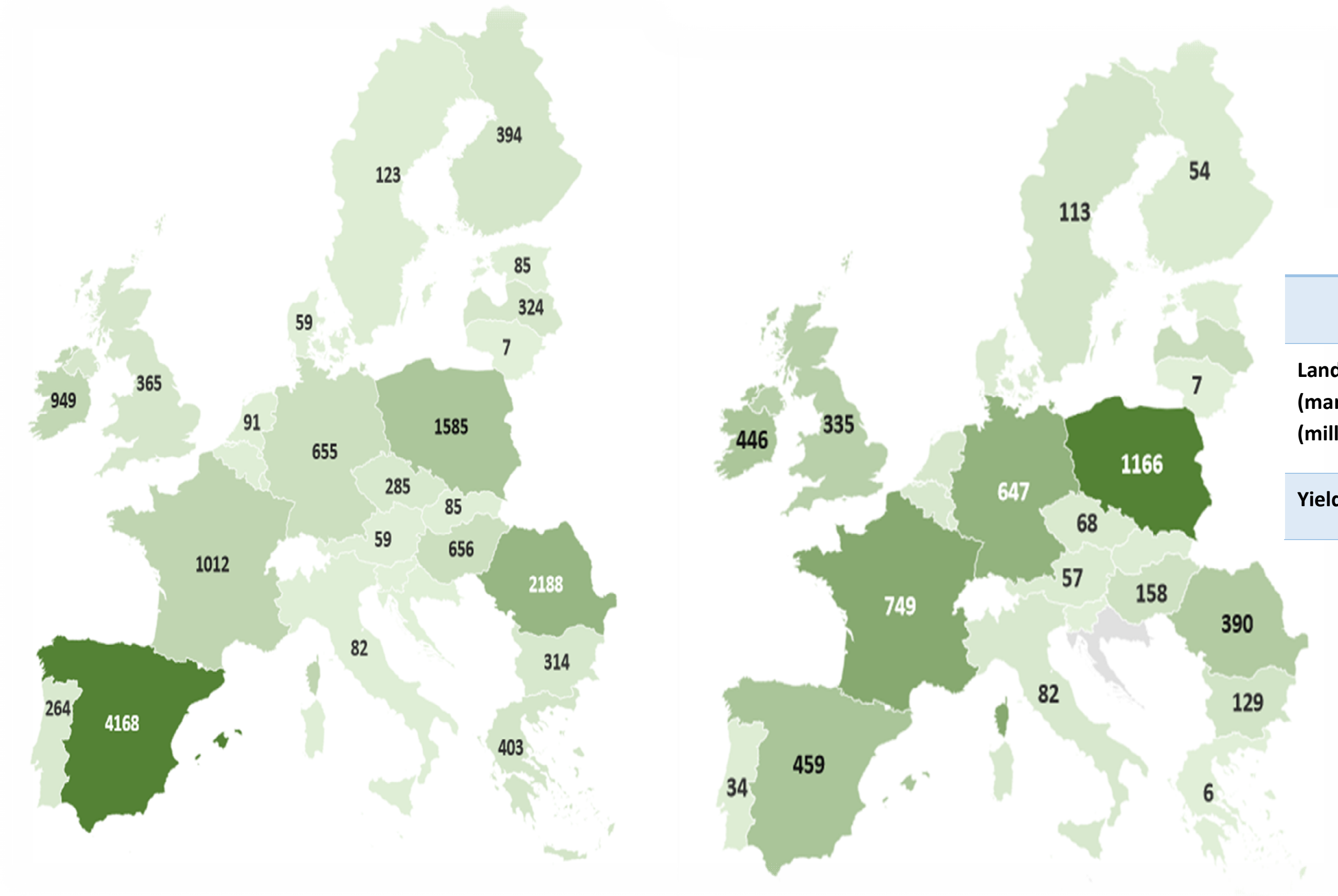




Panoutsou et al., 2017. S2Biom D8.2 Vision for 1 billion dry tonnes lignocellulosic biomass as a contribution to biobased economy by 2030 in Europe

P. Castillo, C. Jacobs-Crisioni, V. Diogo, C. Lavalle. Modelling agricultural land abandonment in a fine spatial resolution multi-level land-use model: an application for the EU. Environ. Model. Softw., 136 (2021), Article 104946, 10.1016/j.envsoft.2020.104946

Low (left)- and high (right)-quality land available for lignocellulosic crops in 2050 (in 1,000 ha)



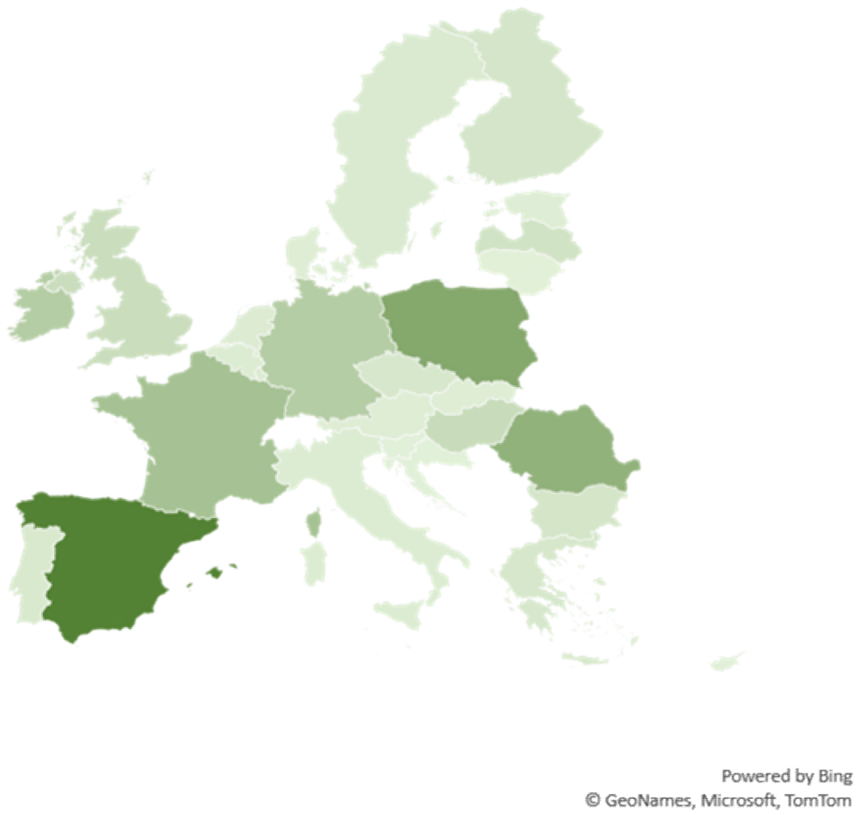
	2020		2030		2050	
	Low quality	High quality	Low quality	High quality	Low quality	High quality
Land availability (marginal lands) (million ha)	13.7	4.6	14.5	5.5	14.5	5.5
Yields (t/ha)	6	8	6.6	8.8	7.8	10.4

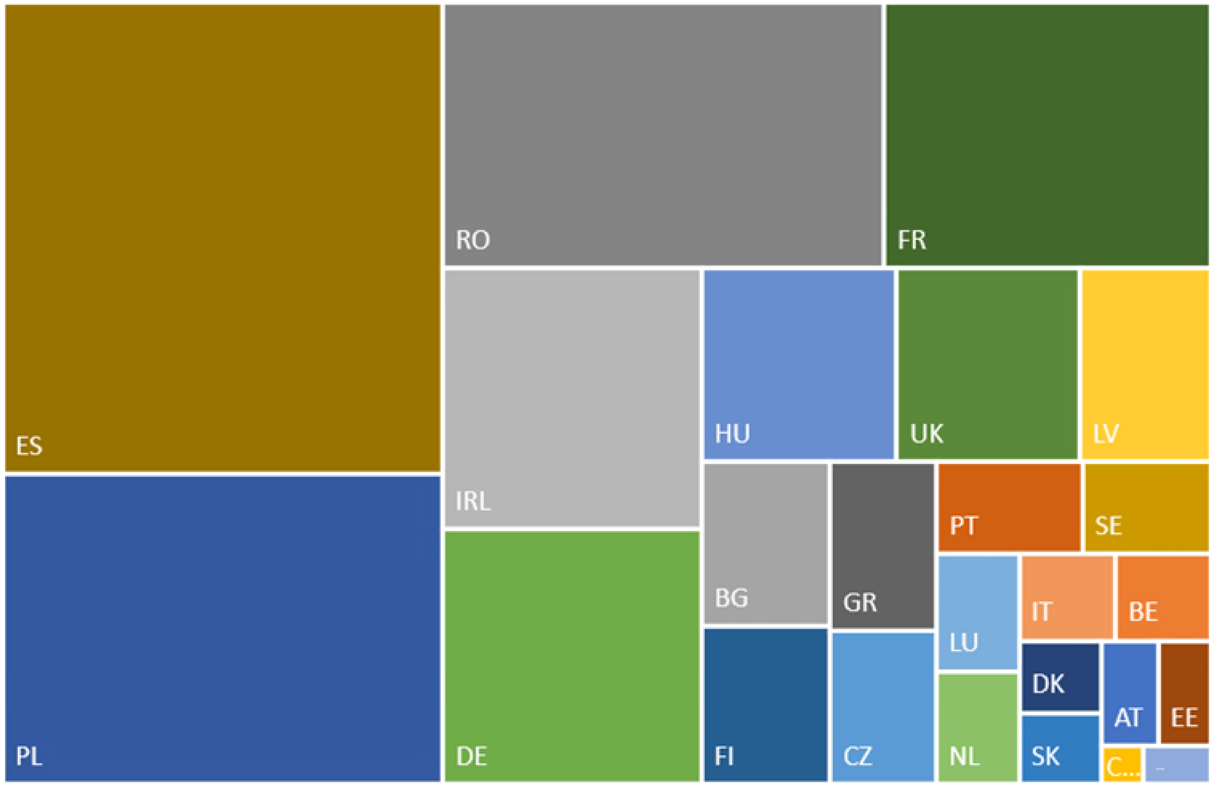
Lignocellulosic crops; structure of their supply chain, climatic and ecological profile

Crop	Structure of the crop supply value chain				Climatic and ecological profile			
	Growth type	Establishment	Harvest	Yield (t/ha)	Soil type/ pH (min- max)	Input	Frost free days	Salt tolerance
Lignocellulosic crops								
Fiber sorghum	Annual	April/ May	Sept/ Oct	15–20	well drained (5.5–7.5)	Average	90	medium
Kenaf	Annual	May	Sept/ Oct	10–15	well drained (4.6–7.5)	Average		
Miscanthus	Perennial	Nov/ Jan	Nov/ Feb	10	variety of soils- well drained (4.5–8.0)	Average	120	
Switchgrass	Perennial	May	Nov/ Jan	8–10	variety- well drained	Low	120	medium
Cardoon	Perennial	Oct or Feb/ Mar	Jun/July	10–15	Low fertility	Low		high
Poplar	Perennial; Harvested every 6–15 years/(in very short rotations every 2–3 years)	April	Nov/ Dec	7–28	Low fertility	Average		
Willow	Perennial; Harvested on 3–4 years rotation	April	Nov/ Dec	10–30	variety of soils	Average		

Panoutsou, C.; Alexopoulou, E. Costs and Profitability of Crops for Bioeconomy in the EU. Energies 2020, 13, 1222. https://doi.org/10.3390/en13051222

Lignocellululosic crops potential 2030-2050





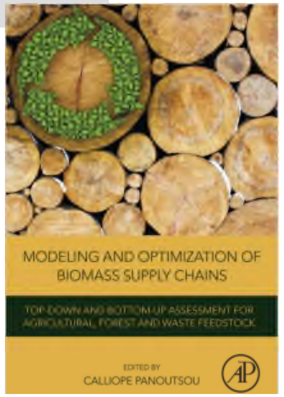
36- 127 million dry tonnes

Forest biomass definitions

Biomass Type	Definition
Stemwood	Part of tree stem with the branches and top removed, with a length of more than 100 cm.
Logging residues	*Woody biomass residues* created during wood harvesting. *Logging residues* include branches and tree tops that can be salvaged when fresh or after seasoning.
Stump	Part of the tree stem below the felling cut. In total-tree utilization the root system is included in the stump.
Other Relevant Definitions Related to Forest Biomass	
Standing volume	Volume of standing trees, living or dead, above-stump measured overbark to top (0 cm). Includes all trees with diameter over 0 cm (d.b.h.).
	Includes: Tops of stems, large branches; dead trees lying on the ground that can still be used for fiber or fuel.
	Excludes: Small branches, twigs, and foliage.
Growing stock	The living tree component of the standing volume.
Net annual increment	Average annual volume over the given reference period of gross increment less that of natural losses on all trees to a minimum diameter of 0 cm (d.b.h.).

Biomass By-product	A secondary product, which is made incidentally during the production of something else (e.g., sawdust when sawing timber).
Bark	Organic cellular tissue, which is formed by taller plants (trees, bushes) on the outside of the growth zone (cambium) as a shell for the wooden body.
Wood-processing industry by-products	*Woody biomass* by-products originating from the wood processing as well as the pulp and paper industry.
	Cross-cut ends: short pieces of *woody biomass* which occur when the ends of logs or sawn timber are cross cutoff, with or without *bark*.
	Edgings: parts of *woody biomass* which occur when trimming sawn timber and which show a remainder of the original rounded surface of the tree, with or without *bark*.
	Slabs: parts of *woody biomass* created when cuts are made into the edges of logs and whereby one side shows the original rounded surface of the tree, either completely or partially, with or without *bark* (approximate length 200–800 cm).
	Sawdust: Fine particles created when sawing wood. Most of the material has a typical particle length of 1–5 mm.
	Wood shavings; cutter shavings: shavings from *woody biomass* created when planning wood.
	Black liquor: liquor obtained from wood during the process of pulp production, in which the energy content is mainly originating from the content of lignin removed from the wood in the pulping process. Black liquor also contains pulping chemicals. Black liquor is not a *solid biofuel*.

M. Lindner, M.G. Dees, P. Anttila, P.J. Verkerk, J. Fitzgerald, P. Datta, *et al.*Assessing lignocellulosic biomass potentials from forests and industry. C. Panoutsou (Ed.), Modeling and optimization of biomass supply chains, Academic Press, London (2017), pp. 127-167

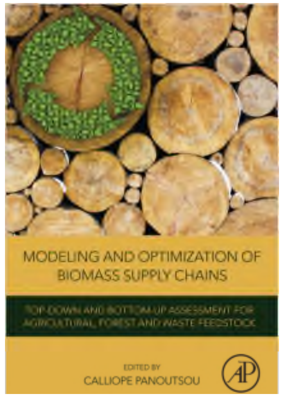


Forest biomass

Type of biomass	Definition	Sustainability issues
Roundwood/ Stemwood	Stemwood from thinnings and final fellings 1. Current stem wood harvests 2. Currently unused stem wood production potential	Soil quality loss, biodiversity risks, Carbon debt
primary residues	1) Early thinning stems 2) Early thinnings crown incl fuelwood 3) Logging residues of final fellings 4) Logging residues thinnings 5) Stump extraction final felling (only where removal of these is common practice, e.g. mostly in Scandinavia) 6) Stump extraction thinnings (only where removal of these is common practice, e.g. mostly in Scandinavia)	Soil quality loss, biodiversity risks, Carbon debt
Sawmill by-products (excl saw dust)	These consist of **bark, slabwood and offcuts.** **Bark** is removed from the stemwood after delivered to the sawmill. **Slabwood** consists of the long rounded sides of the logs that are sawn off the outside in order to produce the main wood products (planks). Slabwood can be available intact as paticles or as chips. **Offcuts** are generated during the sawmilling process, through cutting off edges and trimming of planks and to correct length or to take out defects., usually these offcuts are chipped.	
Sawdust	Sawdust is produced in sawmills when stemwood is cut into planks and other sawmill products. The sawdust is collected to be used in other processes.	Competition
Other industrial residues	Cover all residues produced in wood industries including wood-based panel industry, furniture, (wood)construction material and packaging industry. These residues consist of sawdust, shavings, trimmings, rejections, peeler cores or square-cuttings.	
Black liquor	Black liquor is a by-product from the production of wood pulp for paper making. The pulping process residues mainly consist of lignin and hemicelluloses, cooking chemicals (for pulping) and water. Black liquor results from chemical pulping processes when wood is cooked with appropriate chemicals to separate cellulose fibres from lignin and other wood components.	

M. Lindner, M.G. Dees, P. Anttila, P.J. Verkerk, J. Fitzgerald, P. Datta, *et al.*Assessing lignocellulosic biomass potentials from forests and industry. C. Panoutsou (Ed.), Modeling and optimization of biomass supply chains, Academic Press, London (2017), pp. 127-167

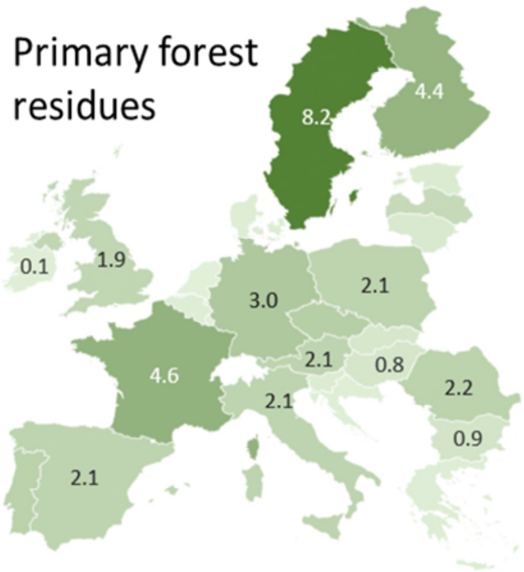
Maximum extraction rates

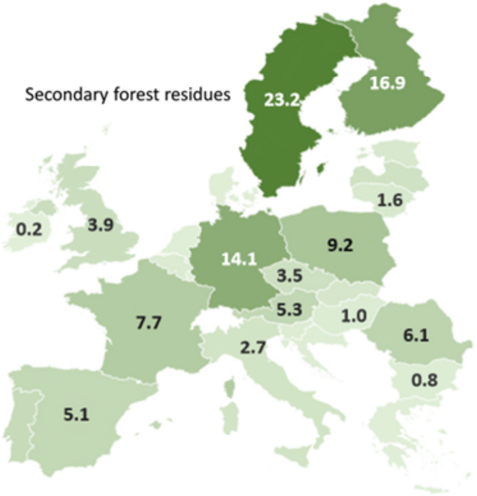


Type of Constraint	Technical Potential	High Potential	Base Potential
Site productivity	Not a constraining factor	Not a constraining factor	35% extraction rate on poor soils (Acrisol, Podzoluvisol, Histosol, Podzol, Arenosol, Planosol, Xerosol); not a constraining factor other soils
Soil and water protection: ruggedness	Not a constraining factor	70% on slopes up to TRI[1] highly rugged; 0% over TRI highly rugged	70% on slopes up to TRI[1] moderately rugged 0% over moderately rugged
Soil and water protection: soil depth	Not a constraining factor	Not a constraining factor	0% on Rendzina, Lithosol, and Ranker (very soil depth)
Soil and water protection: soil surface texture	Not a constraining factor	Not a constraining factor	0% on peatlands (Histosols)
Soil and water protection: soil compaction risk	Not a constraining factor	Not a constraining factor	0% on soils with very high compaction risk; 25% on soils with high compaction risk; not constraining factor on other soils
Biodiversity: protected forest areas	Not a constraining factor	0%; not a constraining factor in areas with high or very high fire risk	0%; not a constraining factor in areas with h very high fire risk
Recovery rate	70% up to TRI[1] highly rugged; 0% over TRI highly rugged	70% on slopes up to TRI highly rugged; 0% over TRI highly rugged	70% on slopes up to TRI moderately rugged; 0% over moderately rugged
Soil-bearing capacity	0% on Histosols, Fluvisols, Gleysols, and Andosols, not a constraint in Finland and Sweden	0% on Histosols, Fluvisols, Gleysols, and Andosols, not a constraint in Finland and Sweden	0% on Histosols, Fluvisols, Gleysols, and An

[1]Terrain ruggedness index

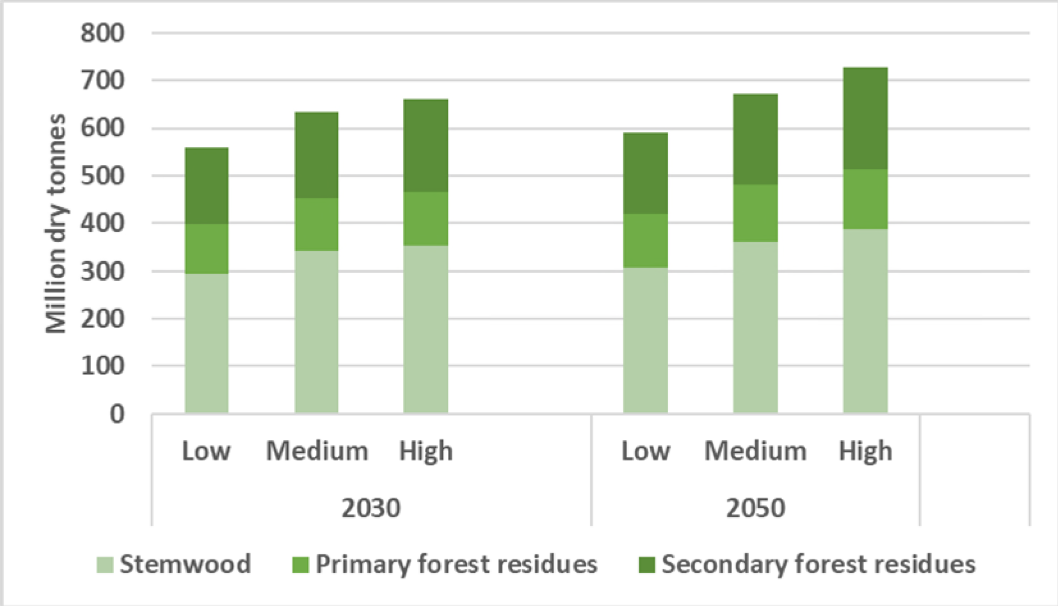
Forest feedstocks





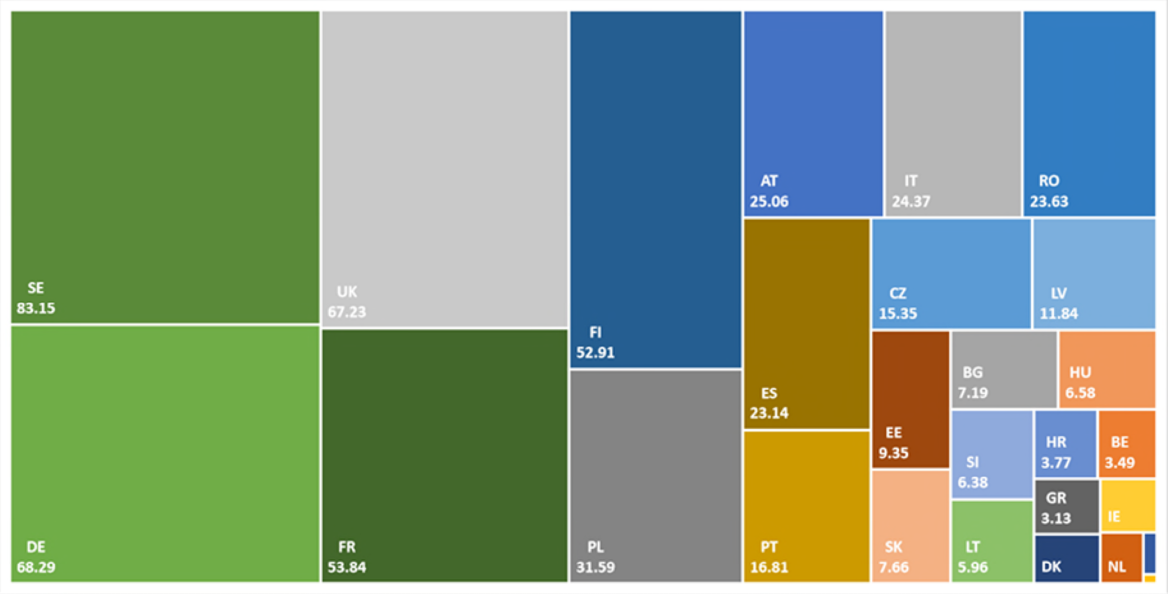
Estimated biomass potential from forestry for all markets

Estimated biomass potential from forestry



558 -726 million dry tonnes

Regional distribution



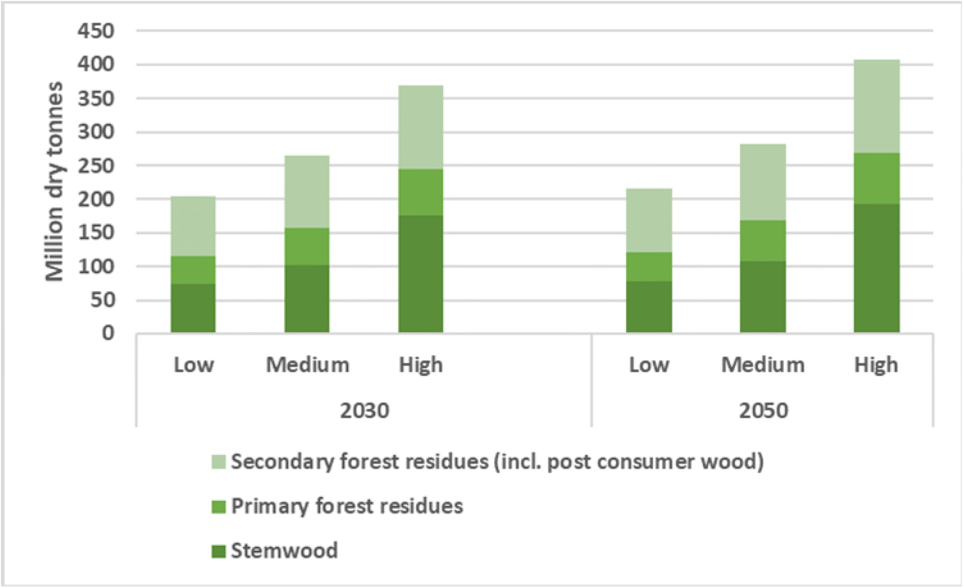
Note: Regional distribution for Scenario 1 (million dry tons).
Similar for Scenario 2 and 3

Key assumptions

	Scenario 1 (Low)	Scenario 2 (Medium)	Scenario 3 (High)
Forestry			
Stem wood used for energy purposes (Current stemwood for energy (fuelwood): 45%)	25%	30%	50%
Primary forestry residues availability for energy production	40%	50%	60%
Secondary forestry residues and post consumer wood availability for energy	55%	60%	65%

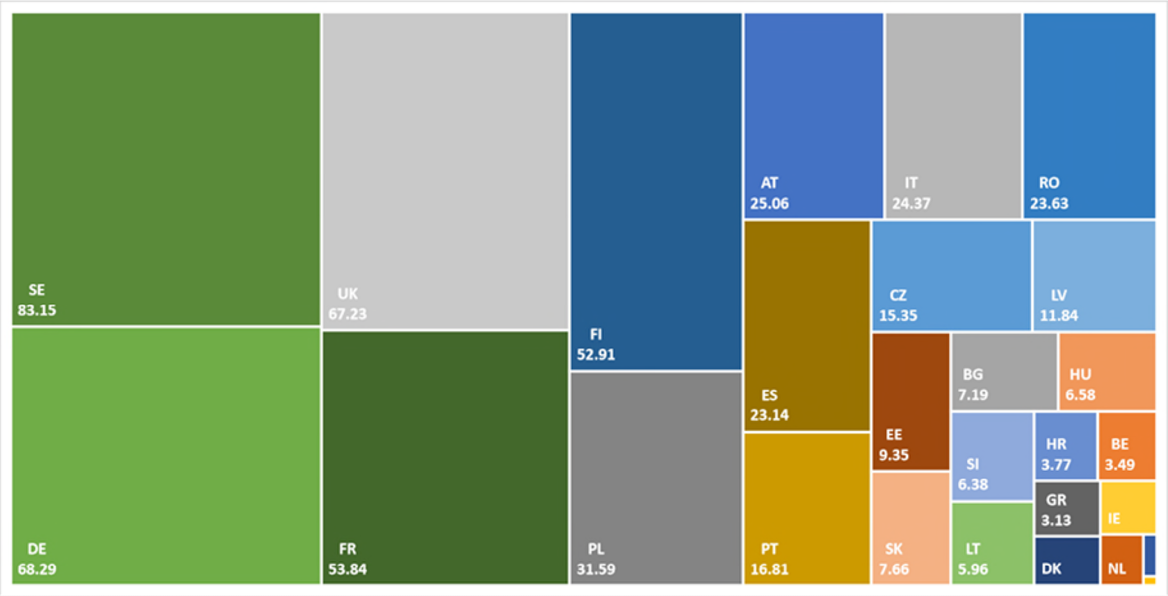
Estimated biomass potential from forestry for bioenergy

Estimated biomass potential from forestry



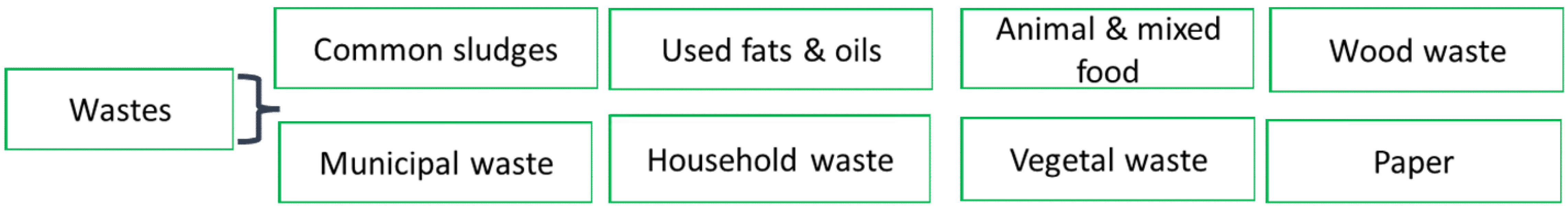
204 -408 million dry tonnes

Regional distribution



Note: Regional distribution for Scenario 1 (million dry tons). Similar for Scenario 2 and 3

	Key parameters	Low	BAU	High
Forestry	Fuelwood	25%	30%	50%



Biowastes

- Eurostat waste generation and waste treatment data
- Projections: waste per category develops over the years according to the population growth for household waste and according to Gross Domestic Product (GDP) growth rate for the Nomenclature of Economic Activities (NACE) waste categories.

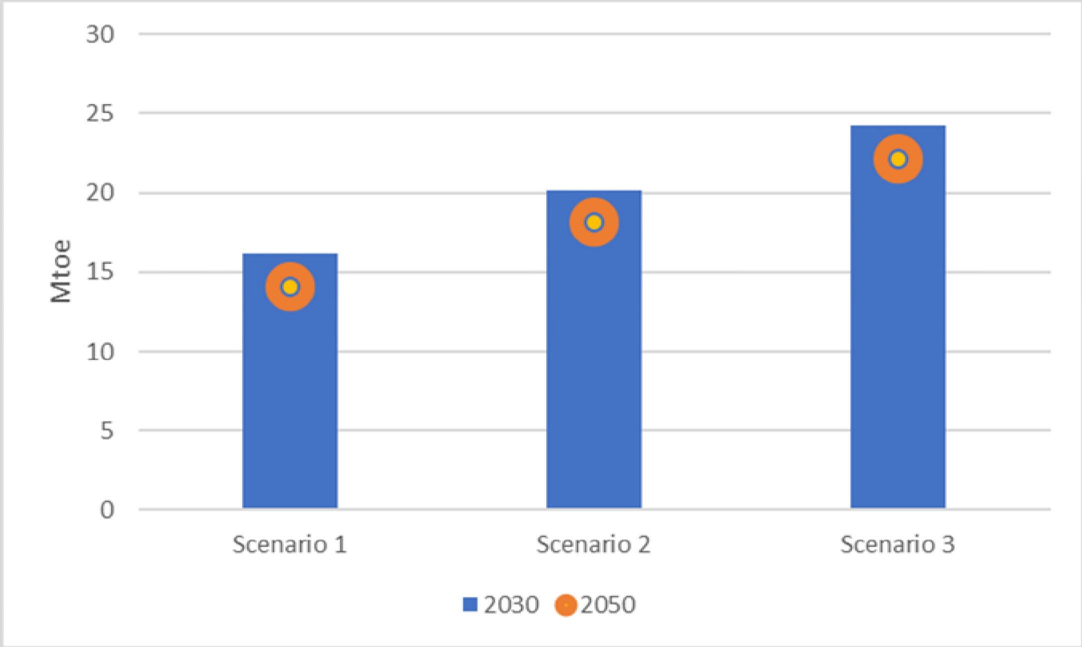
Key assumptions

	Scenario 1 (Low)	Scenario 2 (Medium)	Scenario 3 (High)
Wastes			
Biowaste used for energy production	60% in 2030 (65% in 2050) of biowaste is recycled and 40% in 2030 (35% in 2050) is separately collected and available for bioenergy	50% in 2030 (55% in 2050) of biowaste is recycled and 50% in 2030 (45% in 2050) is separately collected and available for Anaerobic Digestion	40% in 2030 (45% in 2050) of biowaste is recycled and 60% in 2030 (55% in 2050) is separately collected and available for Anaerobic Digestion

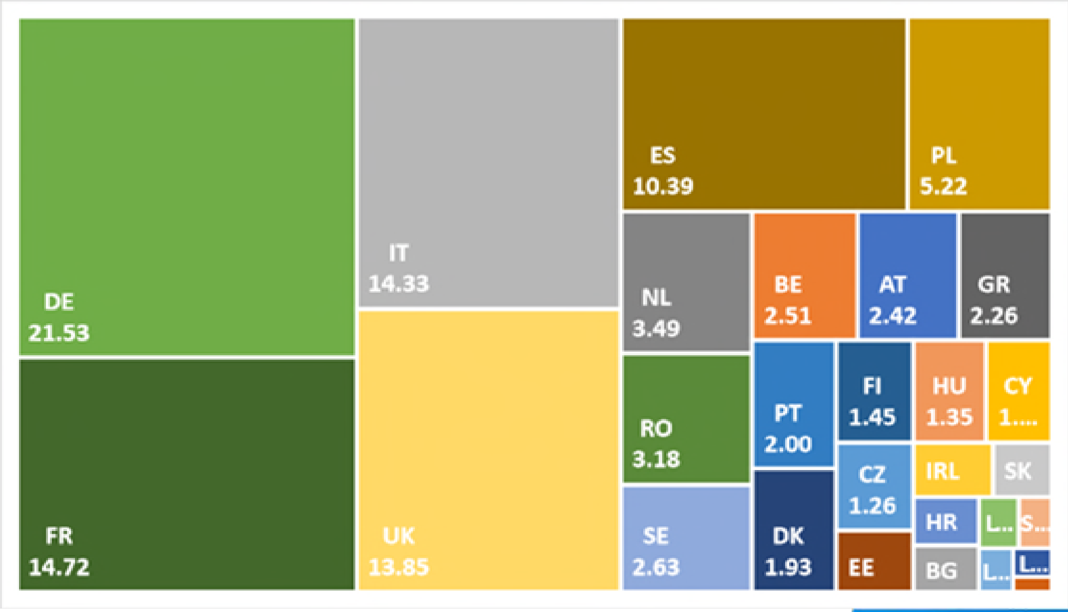
Biowastes

Estimated biomass potential for biowastes for bioenergy

Estimated biomass potential from biowastes



Regional distribution



Note: Regional distribution for Scenario 1 (million dry tons).
Similar for Scenario 2 and 3

	Key parameters	Low	BAU	High
Wastes	Biowastes for energy	35%	45%	50%

Conclusions & the way forward

In a nutshell:

www.economist.com

- Bioenergy **value chains** are **complex.**
- **Efficiency & resilience** (spatial and temporal) **must be optimised.**
- **Clear policy focus** is **essential** to improve performance.
- Defining **priorities** and using **appropriate metrics** can steer support towards targeted interventions that will overcome challenges and improve performance.
- Policies are in place; further **coordination of interventions** that target challenges and are **integrated along the value chain** can help.

Bioenergy value chains

Increasingly varied & innovative

Imperative to comply with resource efficient and sustainable practices

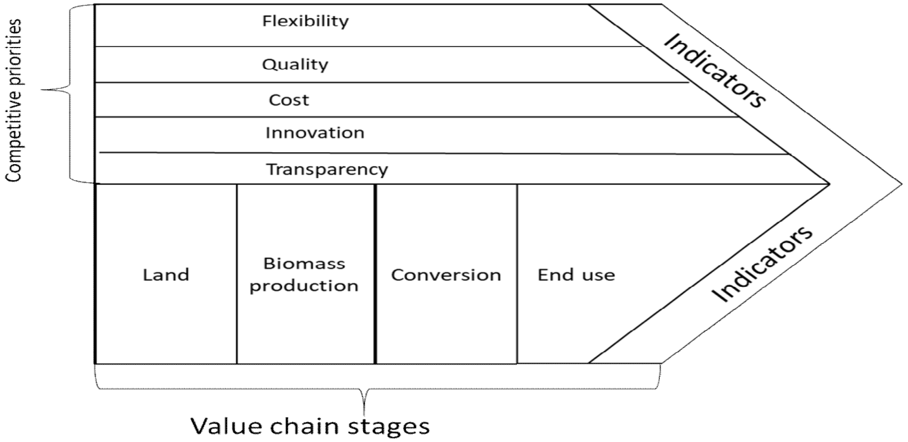
Complex, open-ended or inconsistent, unrelated metrics

Lack of coherence in systems thinking to incorporate challenges

Individual stages within biomass value chains interrelate physical assets with market attributes; this cannot be fully addressed by single target optimisation

Porter, M.E., Competitive Advantage: Creating and sustaining superior performance. Vol. 167. 1985.

Panoutsou, Calliope & Singh, Asha (2020) [A value chain approach to improve biomass policy formation](https://doi.org/10.1111/gcbb.12685). GCB Bioenergy 12 (7): 464-475 https://doi.org/10.1111/gcbb.12685



Imperial College London

Indicators and methodologies for the assessment of resource efficient biomass value chains

Understanding energy systems, model integration and open datasets BY:

- informing the debate on sustainable biomass options that can supply European energy and non-energy sectors on different timeframes by conducting comparative assessments to evaluate the technical, economic, environmental, and social impacts associated with their production and management practices.

Energy Policy
Volume 35, Issue 12, December 2007, Pages 6075-6083

Developing a sustainability framework for the assessment of bioenergy systems

Lucia Elghali [a], Roland Clift [a], Philip Sinclair [a], Calliope Panoutsou [b], Ausilio Bauen [b]

GCB-BIOENERGY
BIOPRODUCTS FOR A SUSTAINABLE BIOECONOMY
Open Access

OPINION | Open Access

A value chain approach to improve biomass policy formation

Calliope Panoutsou, Asha Singh

Energy Policy
Volume 37, Issue 12, December 2009, Pages 5675-5686

Biomass supply in EU27 from 2010 to 2030

Calliope Panoutsou [a], John Eleftheriadis [b], Anastasia Nikolaou [b]

Global Transitions
Volume 2, 2020, Pages 60-75

Competitive priorities to address optimisation in biomass value chains: The case of biomass CHP

Calliope Panoutsou, Asha Singh, Thomas Christensen, Luc Pelkmans

Costs and Profitability of Crops for Bioeconomy in the EU

by Calliope Panoutsou [1,*] and Efthymia Alexopoulou [2]

energies

Socio-Economic Opportunities from Miscanthus Cultivation in Marginal Land for Bioenergy

by Calliope Panoutsou [1,*] and David Chiaramonti [2,3]

energies

Scenario analysis

Collaborative foresight process and forward-looking analysis to explore possible scenarios towards a sustainable, clean, and resource-efficient biomass value chains, with a focus on climate-neutrality and sustainable development.

Biofpr Biofuels Bioproducts & Biorefining

SCI where science meets business

Modeling and Analysis

Bioenergy scenarios that contribute to a sustainable energy future in the EU27

Ayla Uslu, Joost van Stralen, Berien Elbersen, Calliope Panoutsou, Uwe Fritsche, Hannes Böttcher

D6.1: Report on description of baseline scenario for EU bioeconomy and of alternative scenarios for EU's bioeconomy future

biomonitor
Monitoring the Bioeconomy

Revised version 06/20

Authors: Calliope Panoutsou (ICL), Obby Arrekul (ICL), Thomas Christensen (ICL), Asha Singh (ICL), Hans Verkerk (EFI), George Philippidis (CITA), Myrna van Leeuwen (WecR), Viktoriya Sturm (TI), Robert M'barek (JRC) and Justus Wesseler (WUR).

biomonitor **POLICY BRIEF #3**

BioMonitor Policy Scenarios for the European Bioeconomy to 2030 and 2050

Policy analysis

Understanding energy systems, model integration and open datasets BY:

- developing and applying methodologies and tools to analyse the role of biomass in sustainable low carbon futures and the implications for policy areas including energy and environment.

KeAi
CHINESE ROOTS GLOBAL IMPACT
Global Transitions
Volume 3, 2021, Pages 13-42

Policy review for biomass value chains in the European bioeconomy

Asha Singh, Thomas Christensen, Calliope Panoutsou

ELSEVIER
Energy Strategy Reviews
Volume 34, March 2021, 100633

Advanced biofuels to decarbonise European transport by 2030: Markets, challenges, and policies that impact their successful market uptake

Calliope Panoutsou [a], Sonja Germer [b], Paraskevi Karka [c], Stavros Papadokostantakis [c], Yuri Kroyan [d], Michal Wojcieszyk [d], Kyriakos Maniatis [e], Philippe Marchand [f], Ingvar Landalv [g]

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Article

Advanced Biofuel Value Chains through System Dynamics Modelling and Competitive Priorities

Thomas Christensen and Calliope Panoutsou *

Biofpr Biofuels Bioproducts & Biorefining
SCI where science meets business
Perspective

Biomass Futures: an integrated approach for estimating the future contribution of biomass value chains to the European energy system and inform future policy formation†

Calliope Panoutsou, Ausilio Bauen, Hannes Böttcher, Efi Alexopoulou, Uwe Fritsche, Ayla Uslu, Joost N.P. van Stralen, Berien Elbersen, Bettina Kretschmer, Pantelis Capros, Kyriakos Maniatis

Modeling and Analysis

The role of biomass in heat, electricity, and transport markets in the EU27 under different scenarios

Joost N.P. van Stralen, Ayla Uslu, Francesco Dalla Longa, Calliope Panoutsou

Review

Cascading use: a systematic approach to biomass beyond the energy sector†

Dearbhla Keegan, Bettina Kretschmer, Berien Elbersen, Calliope Panoutsou

Co-creation with stakeholders in case studies

Understanding the needs for future policy interventions and how these can be integrated to climate and energy policies

ELSEVIER

Energy Policy
Volume 36, Issue 10, October 2008, Pages 3674-3685

ENERGY POLICY

Bioenergy in Greece: Policies, diffusion framework and stakeholder interactions

Calliope Panoutsou

ELSEVIER

Biomass and Bioenergy
Volume 32, Issue 7, July 2008, Pages 635-653

BIOMASS & BIOENERGY

The potential demand for bioenergy in residential heating applications (bio-heat) in the UK based on a market segment analysis

S. Jablonski, A. Pantaleo, A. Bauen, P. Pearson, C. Panoutsou, R. Slade

S2Biom

Strategic guide for biomass heat policy in Ukraine

Dr Calliope Panoutsou; Imperial College London
Dr Tetiana Zheliezna; REA

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT N. 773501

PANACEA
Non Food Crops for a EU Bioeconomy

D3.2 PANACEA Roadmap
http://www.panacea-h2020.eu/

CELEBio

D.3.1 Guidelines for National Bioeconomy Action Plans

https://celebio.eu/

This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement **No 838087**

Authors: Calliope Panoutsou, Liyana Adjarova, Lora Jibreel, Dinko Đurđević, Željka Fištrek, Biljana Kulišić, Ana Mandarić, Markus Dettenhofer, Éva Hunyadi Borbélyné, Márta Szabó, Miha Koprivnikar Krajnc, Stefan Vratny and Dominica Jendrusova

November 2020

Thank you!

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Imperial College London